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Abstract

Low order streams dominate drainage networks and have been documented to transport substantial amounts of energy and nutrients to downstream habitats. Information is needed, however, concerning how such subsidies vary across climatic and disturbance gradients. The goals of this research are to: 1) develop and test methods for monitoring headwater stream conditions at the subcatchment and stream levels, 2) determine the effects of land-use (timber harvest and roads) and ecoregion (wet / dry) on the biological productivity of subcatchments, and 3) use this information to relate watershed condition of fishless subcatchments to fish communities in downstream habitats. Our headwater-monitoring program focuses on food web productivity (i.e., the amount of aquatic arthropod biomass and organic detritus produced and exported to fish habitats) as an integrator of the processes and environmental constraints driving these ecosystems. It is also meant to determine whether food web productivity is a key determinant of the health of downstream fish communities. We have selected 60 stream sites located within the Wenatchee subbasin for sampling. Half (30) of these streams are located in Ecological Sub-Region (ESR) 4 (wet ecoregion) with the other 30 in ESR 11 (dry ecoregion). Differences among ecoregions are designated by differences in vegetation type, temperature, precipitation, and solar radiation (Hessburg et al. 2000). In both ecoregions, 15 low (little past logging and presence of roads) and high impact (recent logging and roads) sites have been chosen. The effect of ecoregion has dominated our early results with dry sites transporting more invertebrates downstream and differing in several abiotic variables (e.g. higher conductivity and pH). How these subside potentially influence downstream fish assemblages will be the primary focus of future research.

Introduction

Low-order streams (≤ 1st order; typically fishless streams) comprise more than 80% of drainage networks, yet little is known about the role they play in affecting downstream fish habitats and communities (Benda and Dunne 1997, Gomi et al. 2002). Wipfli and Gregovich (2002) found that small fishless streams can be important energy sources for downstream food webs in southeastern Alaska, transporting invertebrates and organic material produced in headwaters environments to habitats lower in the drainage that contain fish. Understanding the ecological function of these headwater channels and associated subcatchments, and developing monitoring tools for assessing their condition is crucial for a broader understanding of basin-wide watershed condition, and for restoration effectiveness monitoring. Techniques developed by Wipfli and Gregovich (2002) in southeastern Alaska could prove very effective for assessing the biological condition of small drainages in general, and therefore the cumulative effects of land use and watershed condition. Coupled with measuring selected fish community metrics (e.g., lipids, density, growth rates, etc.) in the habitats these small streams drain into, we intend to link watershed condition with stream productivity, food resources for fishes, and ultimately fish condition.

This work represents an opportunity to develop a novel, innovative approach for watershed assessment by directly monitoring the productivity of food webs (arguably the ultimate response of the health of stream ecosystems), and indirectly all the cumulative processes and factors (e.g., organic / inorganic matter load and dynamics, flow regime, light, nutrient dynamics, water temperature, geology, land-use, and watershed condition) that drive it. It is important to emphasize that this work focuses on food web productivity of low order streams as a means for testing and developing a new tool for monitoring watershed condition and restoration effectiveness. This approach is novel for three reasons: (i) food web monitoring gets right to the bottom line and integrates the stressors, processes, and conditions that ultimately drive these ecosystems; (ii) it directly links headwater condition and downstream fish productivity; (iii) these low order watersheds comprise over 80% of typical drainage networks, therefore in aggregation have great potential to influence salmonid habitats downstream; and (iv) monitoring in these low order watersheds has been historically ignored.

Objectives

The objectives of our research include:

Objective 1: Develop and test methods for monitoring subcatchment and stream condition of low-order drainages.

Rationale: The productivity of a stream is a reflection of the health and condition of the watershed it drains. By measuring detritus and invertebrate transport from headwaters (surrogates of headwater production) at a point along the length of a stream, we can assess the level of productivity, and therefore health and condition of a headwater subcatchment upstream of the sampling site. We intend to test methods in the Wenatchee River Basin for monitoring headwater subcatchment condition that were developed by Wipfli and Gregovich (2002) for southeastern Alaska streams. Data suggest this technique holds promise as a surrogate of headwater subcatchment productivity, can serve as a tool for assessing the cumulative impacts of multiple stressors in subcatchments, and can be used as an indicator of watershed condition and health.

Objective 2: Determine the effects of land-use and vegetation cover on biological productivity of headwater subcatchments.

Rationale: Stream productivity and community structure are tightly linked to riparian zones and surrounding vegetation. Land-use and watershed condition affect riparian forest conditions and functionality, which in turn affects the biological productivity of associated aquatic ecosystems. We will show that we can use the methodologies developed under Objective 1 to directly monitor the effects of land-use and vegetation cover on the biological productivity of headwater subcatchments. If we are successful, this monitoring tool will provide a simple and relatively cost-effective technique for long-term monitoring of headwater subcatchments by management agencies.

Objective 3: Link land use, vegetation cover, and watershed condition of fishless subcatchments to fish communities in downstream habitats.

Rationale: Headwater channels can be important sources of nutrients and carbon for fish-bearing habitats in lower parts of drainages (Wipfli and Gregovich 2002). Transport of food to fish-bearing food webs may therefore have profound effects on the fish in lower reaches, including their demographics, and condition. We propose to use fish densities, growth rates, lipid levels, and stable isotopes as indicators of fish health to demonstrate the ecological connectedness between upland fishless habitats and lower fish-bearing habitats (via the food that these subcatchments deliver to fish). We also propose to use this approach to facilitate the connection between land-use and vegetation cover condition in headwater forests with watershed condition downstream, particularly for anadromous salmonids.

Project Area

We have selected 60 stream sites located within the Wenatchee subbasin for sampling. Half (30) of these streams are located in Ecological Sub-Region (ESR) 4 (wet ecoregion) with the other 30 in ESR 11 (dry ecoregion). Differences among ecoregions are designated by differences in vegetation type, temperature, precipitation, and solar radiation (Hessburg et al. 2000). In both ecoregions, 15 low (little past logging and presence of roads) and high impact (recent logging and roads) sites have been chosen. Of the ESR 11 sites, 10 occur in the Mission Creek and 20 occur in the Peshastin Creek drainages. In ESR 4, six occur in the Icicle, nine in Nason Creek, 10 in Little Wenatchee, and five in the White River drainages.

Methods & Materials

In September and November 2004, and February, April, June, and August 2005 we collected aquatic invertebrate and organic/inorganic drift in either a subset of streams (September to February) or all sites (April, June, August). An approximately equal number of streams were used from each category (wet and dry ecoregion crossed with low and high impact), when subsets of sites were sampled. Replicates were streams within each land-use and ecoregion (n = 15), and streams were sampled continuously for invertebrates and detritus over a 24-h period.

Samples were collected using a 250-μm net attached to one end of a 75-cm long, 12-cm diameter plastic pipe frame, which rested on the stream bottom. Both stream and pipe discharge was measured during each sampling period, a mean calculated, and this value used to determine the density of invertebrates (individuals m^{-3}), organic, and inorganic matter (g m^{-3}). Many streams were sufficiently small to allow for the entire stream flow to pass through the pipes. When not, the percentage relative to the total stream flow was determined by our discharge estimates. This fraction was used to extrapolate the transport measured through the net for the whole stream.

Invertebrates were sorted from detritus after being placed in 70% EtOH, and identified to family, body lengths measured, and dry mass determined using taxon-specific length-mass regression equations (Rogers et al. 1977; Smock 1980; Meyer 1989; Sample et al. 1993; Burgherr and Meyer 1997). The remainder of the sample (detritus component) will be oven-dried, weighed, ashed (at 500º C for 5 h), and reweighed to determine ash-free dry mass (AFDM).

Temperature data loggers are employed at all streams and basic water chemistry (pH, DO, conductivity) was collected when sampling. Water samples were also collected at all sites in May and July 2005 to analyze total nitrogen, total phosphorus, nitrite, nitrate, ammonia, and phosphate. In June and August 2005, 24 streams were selected (six from each of the four categories of streams) and sampled for both benthic invertebrates and algae. These data will be compared to drift rates from the same streams to investigate relationships among benthic invertebrate and algae density and drift.

Riparian vegetation cover and composition was calculated along a 200 m reach upstream of sampling sites at all 60 streams. Using a densiometer at five m intervals, total canopy coverage, proportion conifers, proportion deciduous, and the proportion of alder was calculated to relate these variables to headwater transport downstream.

Fish were captured downstream of sampling sites at eight streams using both dip and seine nets. We anesthetized individuals of all species with MS-222® and use gastric lavage techniques (Meehan and Miller 1978) to obtain a sample of consumed prey. Gut contents were preserved in alcohol and will be analyzed in the laboratory to determine whether the assemblage of taxa consumed by fish can be linked to headwater production.

Results Summary

A total of 254 drift samples have been collected to date, with 23 sites sampled in September 2004, 31 in November 2004, 20 in February 2005, and all 60 sites sampled in April, June, and August 2005. We have begun to process and analyze our samples to determine the number and biomass of invertebrates, and the mass of both organic and inorganic matter captured from each of the sampled streams. We also have initiated analysis for the basic water chemistry data (temperature, conductivity, dissolved oxygen, pH), and nutrient data (e.g. nitrogen and phosphorus).

The ecological subregion factor is dominating our preliminary results. Streams within the dry ecoregion have thus far significantly higher conductivity, pH and number and biomass of invertebrates drifting than other sites. However, these results do not include invertebrate, organic, and inorganic data from the spring and summer sampling. We hypothesize that with further data analysis and sampling of all streams over the next year, sites will cluster into four groups based on ecoregion and land use. For example, we have completed initial reach scale vegetation analysis at all of our streams. There is substantial variation in the proportion of conifers and deciduous species located in surrounding riparian zones. Of particular interest is the higher density of alder species that surround streams that have been recently logged, since this variable has been documented to affect invertebrate subsidies in Alaska.

Objective 1 has been accomplished as the methodologies and protocols developed by Wipfli and Gregovich (2002) for southeastern Alaska streams have been directly transferable to the Wenatchee sub-basin. Future data analysis and collection over the next year will fully accomplish objective 2 as ecoregion scale effects already appear to influence headwater subsides. Furthermore, determining how riparian and catchment scale vegetation and land use affect headwater subsidies, is a primary goal of fiscal year 2006.

Only preliminary fish data has been collected in some streams and analysis of their gut contents has only just begun. However, ecoregion effects are apparent here as well given the presence of only rainbow trout in the dry ecoregion and cutthroat trout in the wet ecoregion. Further quantification of fish responses (diet, growth, lipids) will be the major focus during the Spring/Summer 2006 sampling. The current drought in areas surrounding the Wenatchee National Forest could potential move some fish populations further downstream of current sampling sites (J. Kill personal communication). Any such changes will be investigated in October 2005 during the next round of stream sampling.

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